Influence of temperature and salinity data assimilation on an operational forecast model for the North and Baltic Seas

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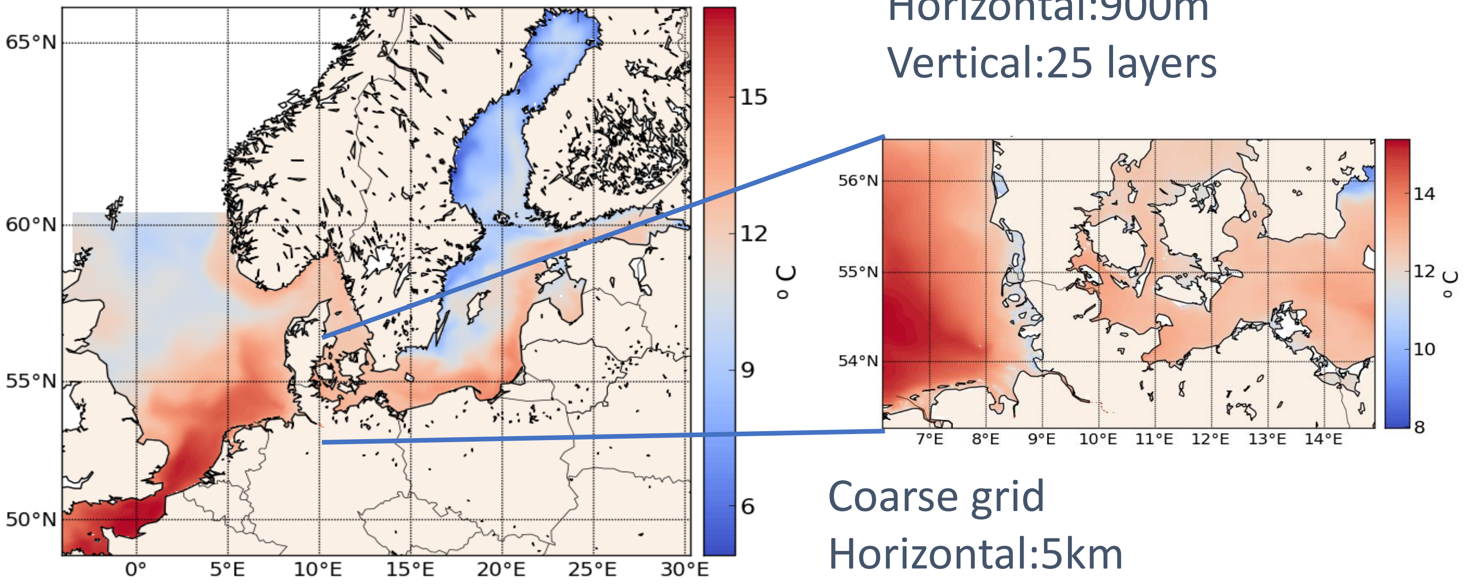
COSS-TT Meeting, 17th June 2025

Introduction

- Forecasting physical and biogeochemical variables in marginal and coastal seas remains challenging due to:
  - Complex dynamics
  - Limited observational data.
- Regional data assimilation (DA) plays a crucial role in delivering accurate, near-real-time marine information by integrating sparse observations with model estimates to generate the most reliable assessments of the ocean state.
- Sea surface temperature (SST) DA improves ocean forecasts in regions such as the Baltic Sea and the Northwest Shelf.
- Two DA experiments were conducted to evaluate the effect of assimilating multiple datasets on improving forecast accuracy.

Operational Model

HIROMB-BOOS-MODEL (HBM)
coupled to
Ecological ReGional Ocean model (ERGOM)



Fine grid
Horizontal:900m
Vertical:25 layers

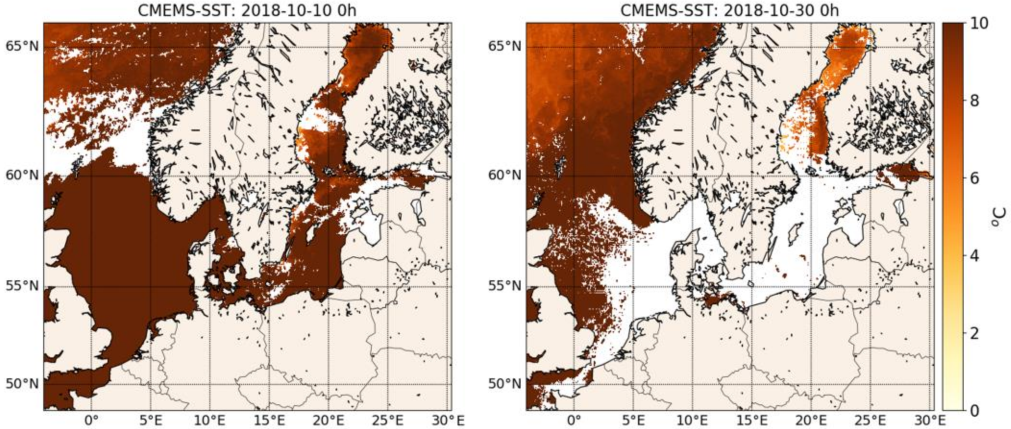
Coarse grid
Horizontal:5km
Vertical:36 layers

- The model domain extends longitudinally from 4°W to 30.5 °E and latitudinally from 48.5 °N to 60.5 °N.
- The model is coupled with the DA component - Parallel Data Assimilation Framework (PDAF)
  PDAF is an open-source data assimilation software that can be used for ensemble data assimilation

Assimilated data

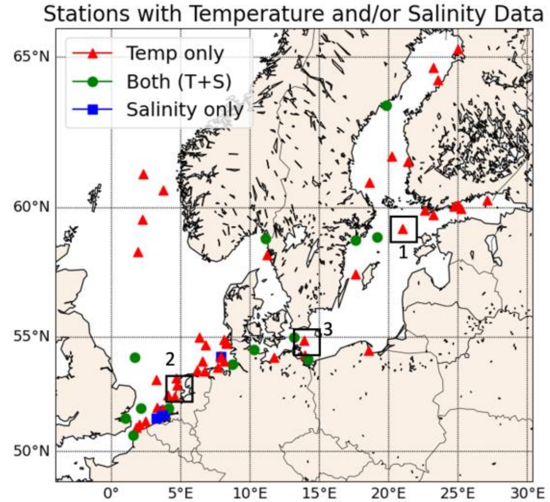
CMEMS satellite SST

- Horizontal resolution – 0.2 x 0.2 degrees
- Available at midnight (00hr)
- Surface/skin temperature
- Data period – October 2018 to September 2019

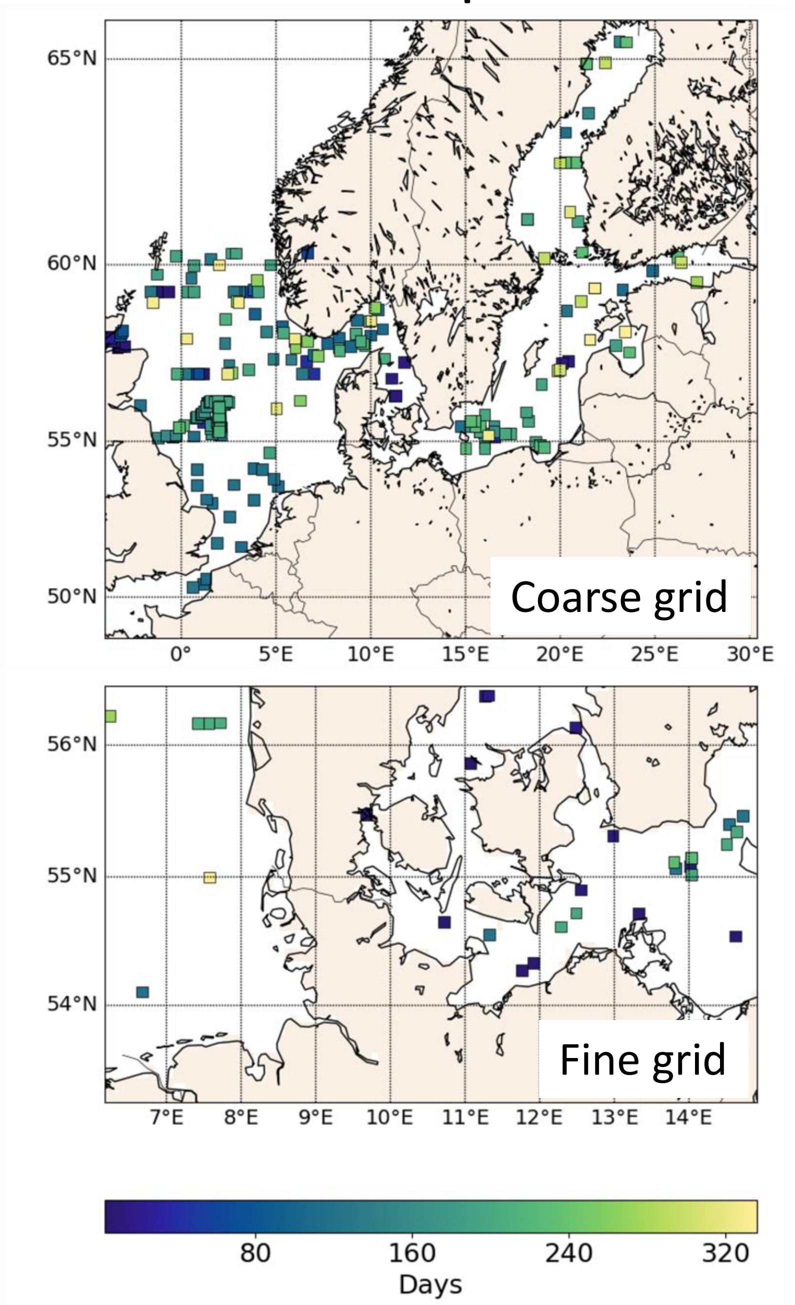


In situ data (Temperature and salinity)

- 39 stations – North Sea
    - 33 stations provide temperature data
    - 19 stations provide salinity data.
- 26 stations - Baltic Sea
    - All stations provide temperature data
    - 7 stations provide salinity data.
- Assimilation :
    - 00 hr and 12 hr



Independent data validation : EN4 data



EN4 data locations available for the North and Baltic :
October 2018 – September 2019

- Sufficient coverage over the North and Baltic Seas.
- Over 65% of data points have only one data entry per year.
- In the southern North Sea (coarse grid), data is only available in the first 3-4 months of the assimilation period.
- Average error values are calculated over the year to analyze model improvement.

Data Assimilation set up

Free run – without any data assimilation

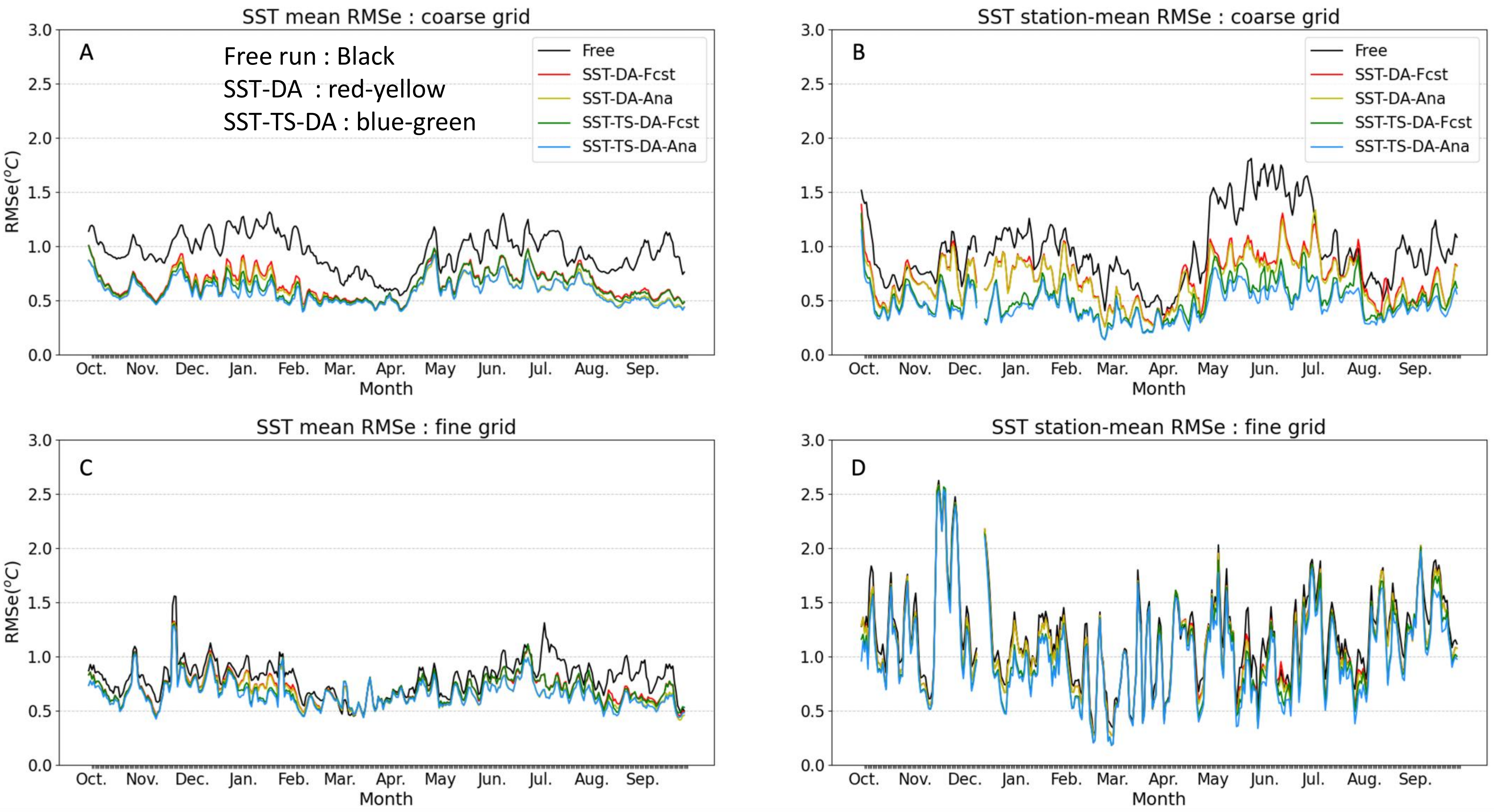
Satellite SST data assimilation (SST-DA)

Satellite SST + in-situ data assimilation (SST-TS-DA)

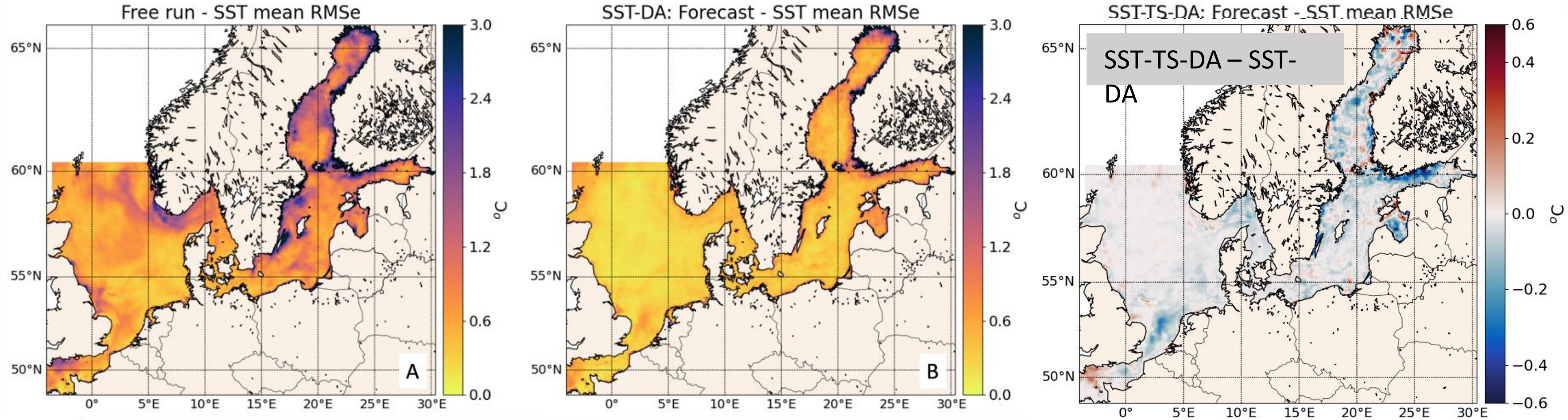
- In-situ assimilation performed every day at:
  - Mid-night (00:00:00)
  - Noon (12:00:00)
- Localization radius for in-situ temp:
  - Coarse grid (rg) - 90 km
  - Fine grid (rf) - 20 km
- Localization radius for in-situ salt:
  - Coarse grid (rg) - 30 km
  - Fine grid (rf) - 10 km

- Experiment time period :
  - October 2018-September 2019
- Filter type used - Local Error Subspace Transform Kalman Filter (LESTKF)
- 40 ensemble members.
- DA run - weakly coupled
- Satellite SST
  - Localization radius :
    - Coarse grid (r_g)- 30 km
    - Fine grid (r_f)- 5 km
  - assimilation performed every day at:
    - Mid-night (00:00:00)

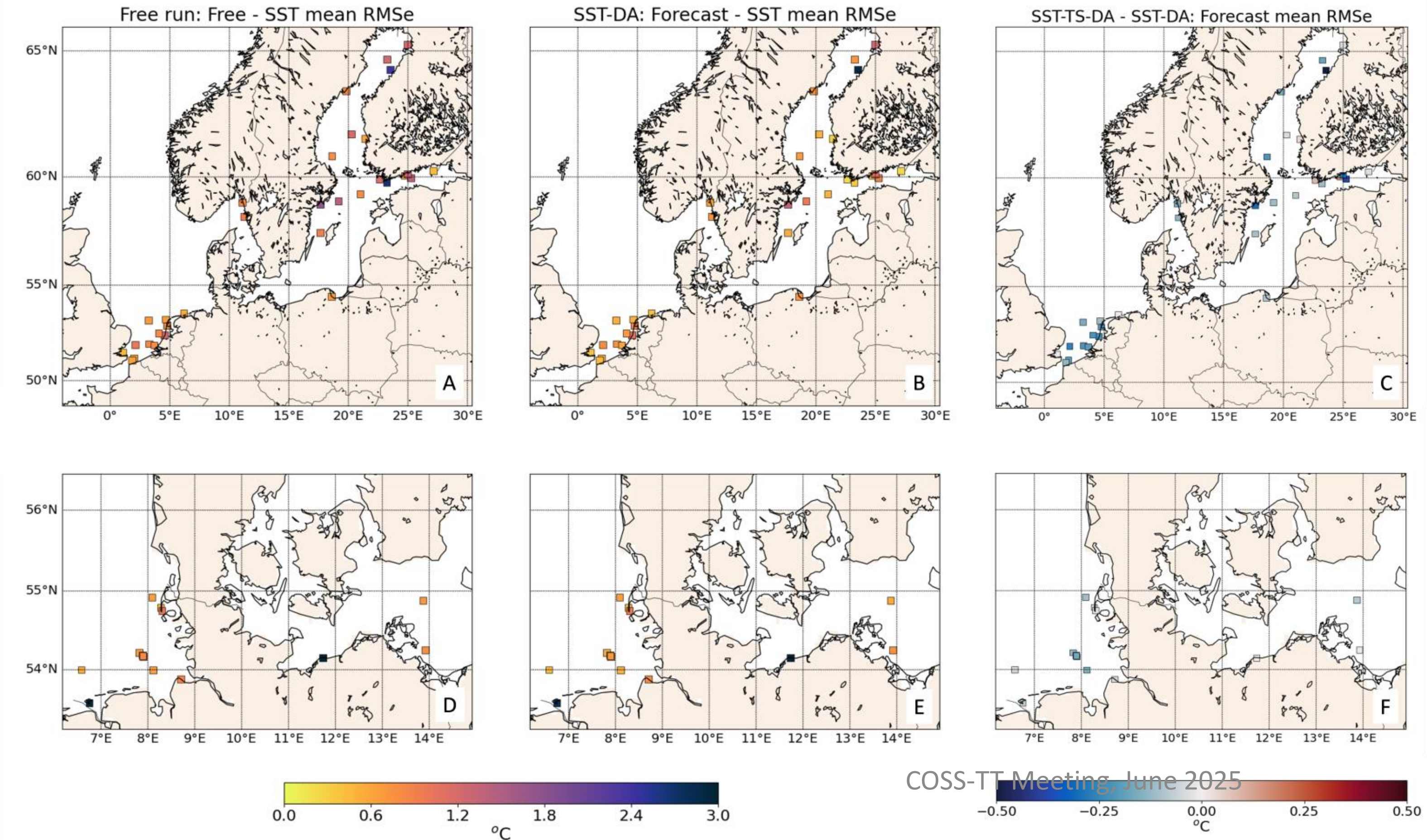
Assimilation results : SST



- Coarse grid RMSE (with regard to station data):
    - By 47 % in SST-TS-DA
    - By 27% in SST-DA
- Fine grid: smaller reduction
    - 11 % in SST-TS-DA
    - 5 % in SST-DA



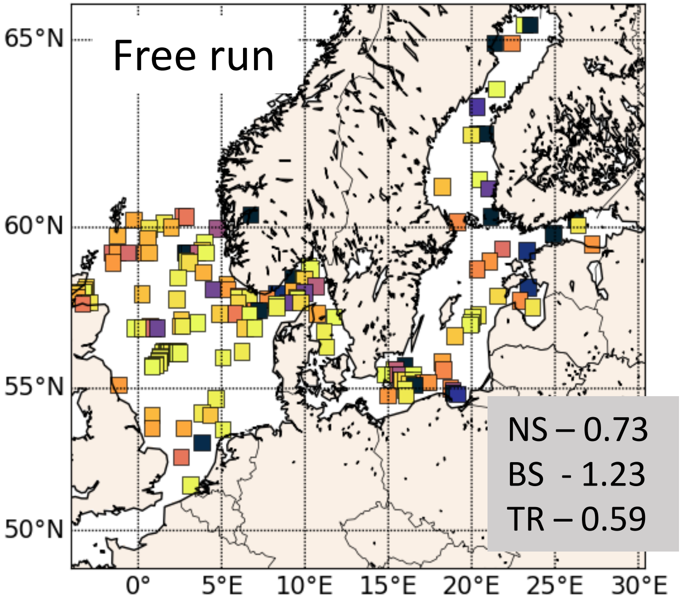
Satellite

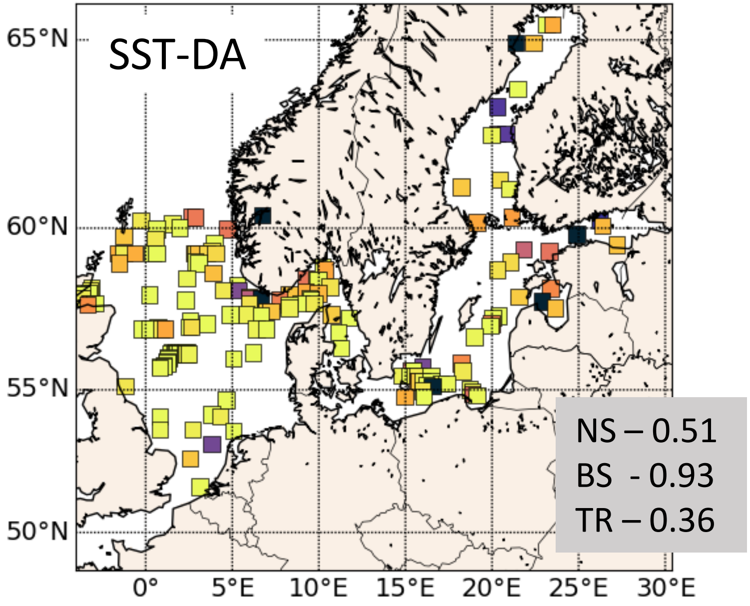


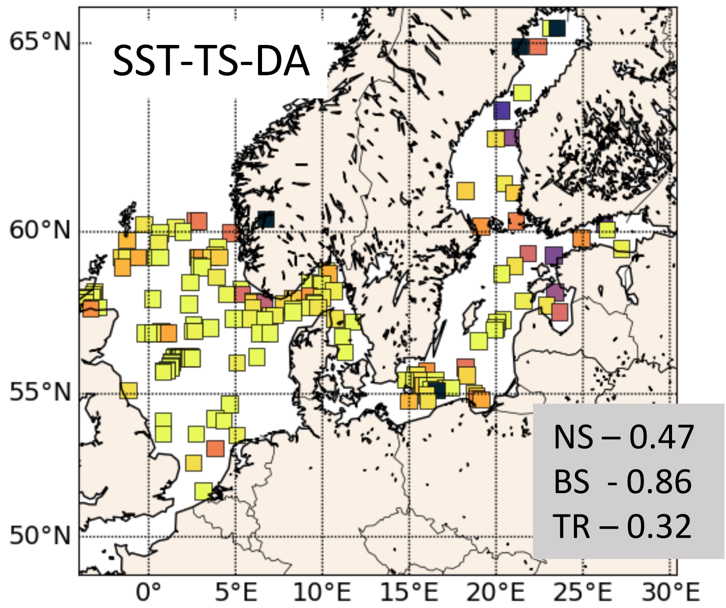
In-situ

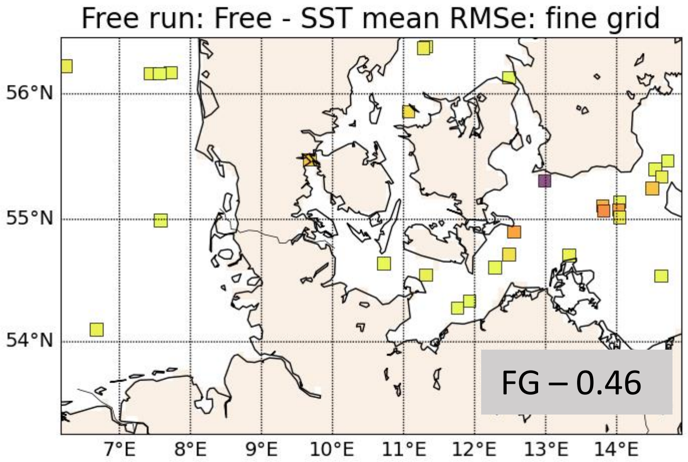
SST-TS-DA performs better than SST-DA.

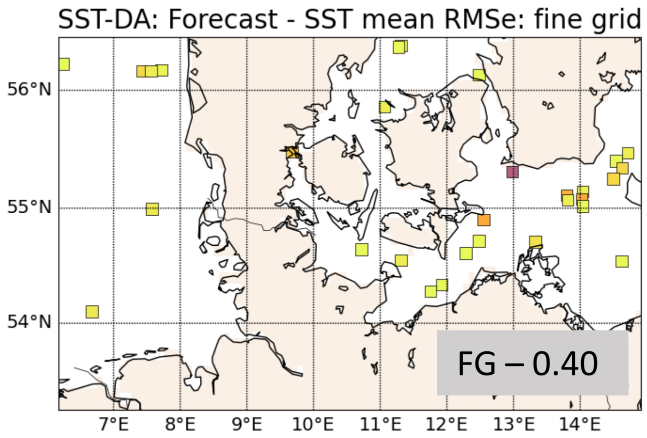
Independent SST data validation : EN4 data

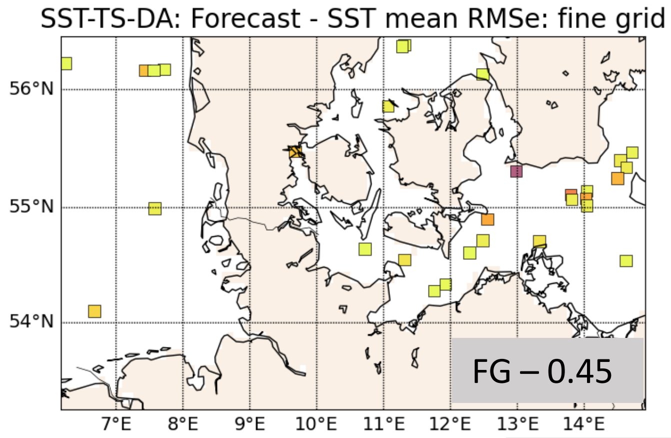


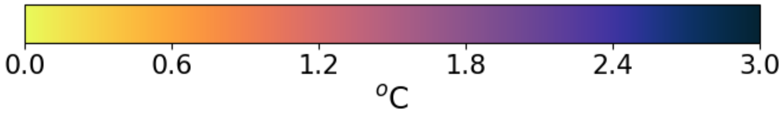






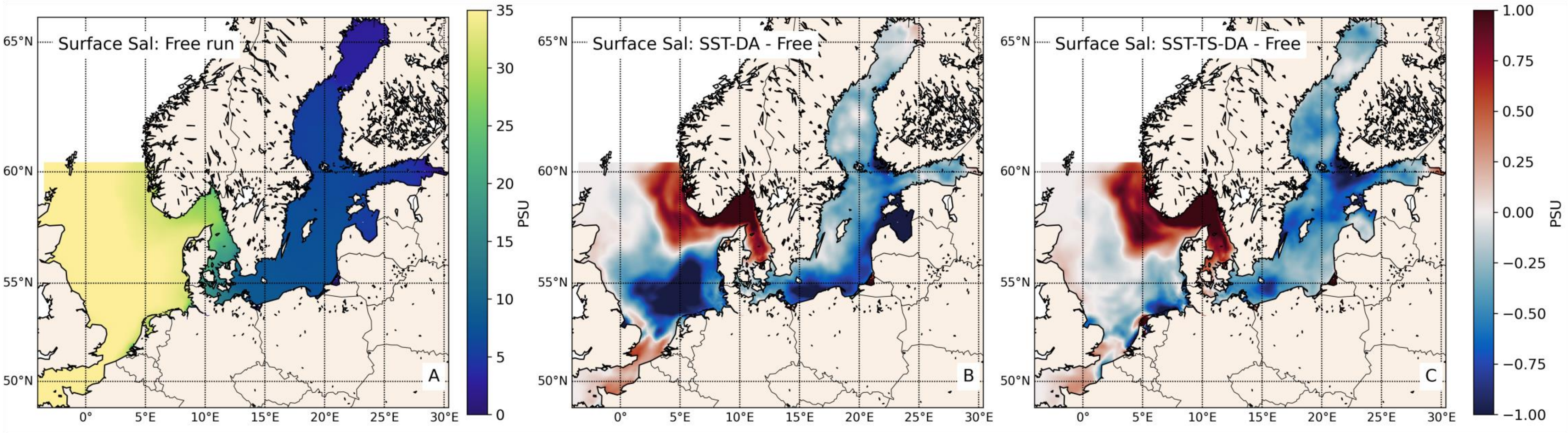






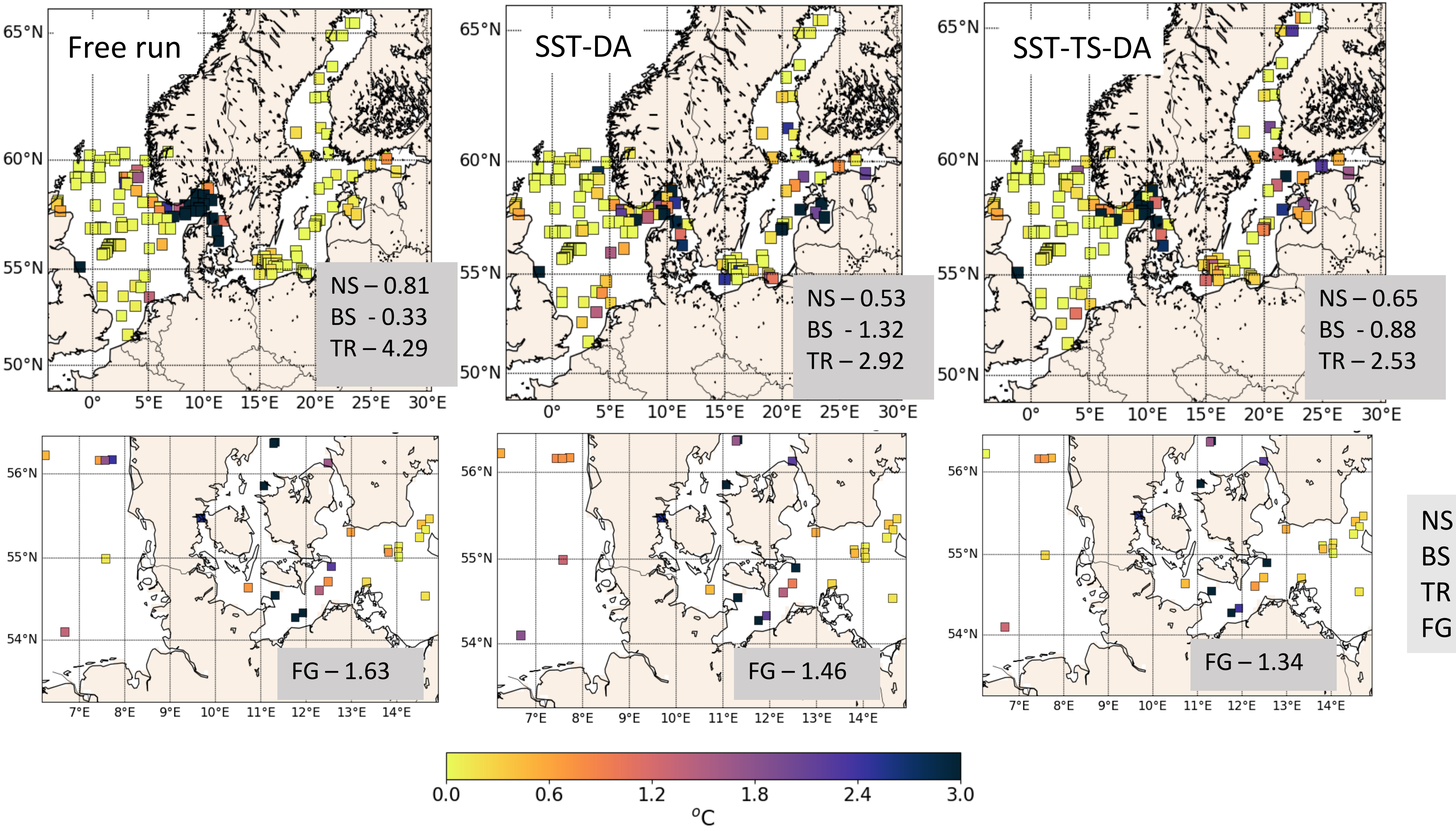
NS : North Sea
BS : Baltic Sea
TR : Transiiton region
FG : Fine grid

Assimilation results : SSS



- SST-DA:
  - Strong SSS reduction in central North Sea.
- SST-TS-DA:
  - Lower SSS reduction in central North Sea, but slight increase along Norwegian & Swedish coasts.
  - Southern North Sea station data limits extreme SSS changes.
  - Baltic Sea:
    - Southern Baltic & Gulf of Riga: Lower SSS reduction due to station data assimilation.
- Gulf of Riga changes are likely dynamic effects (no station data present).

Independent SSS data validation : EN4 data



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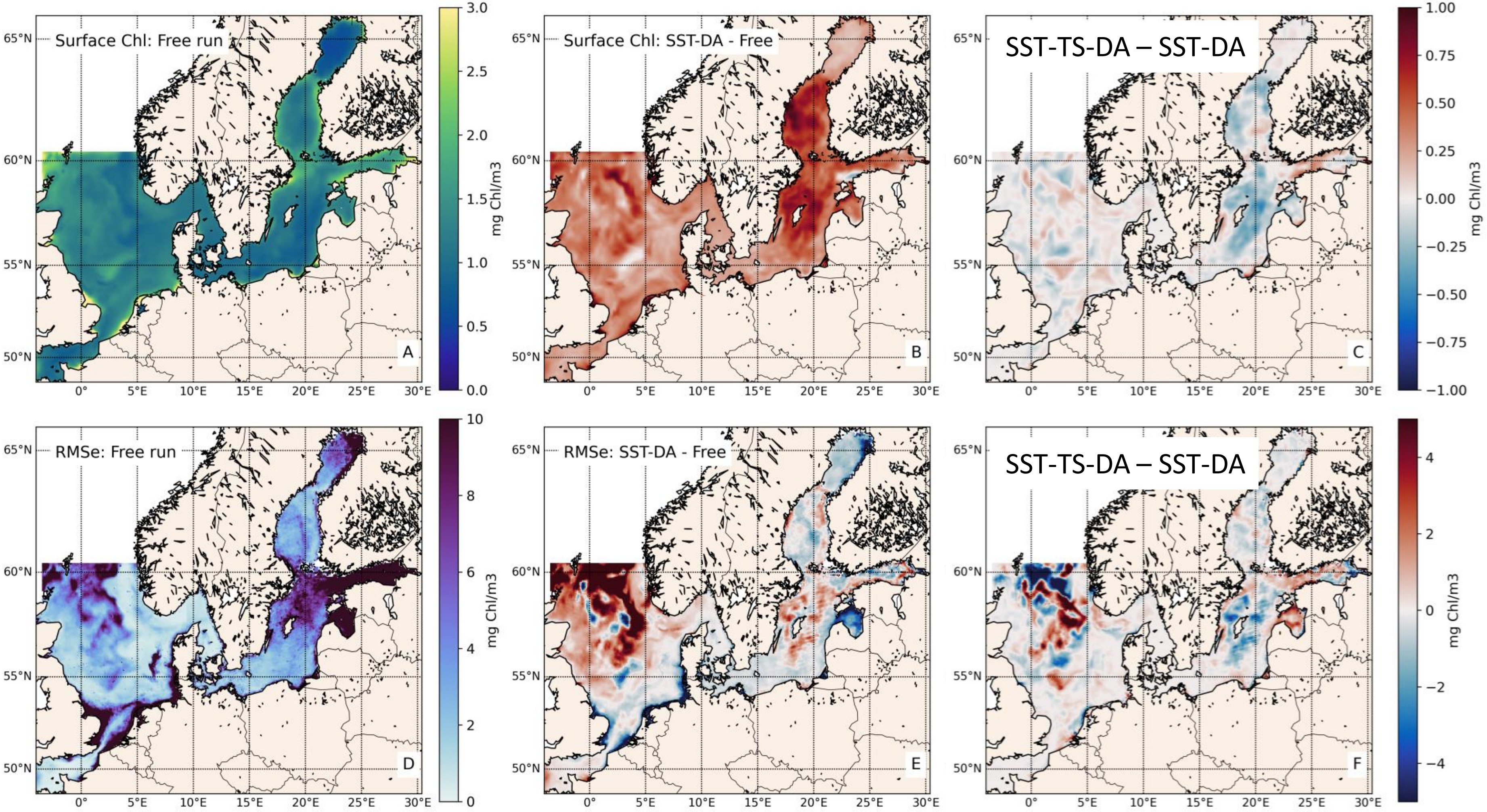
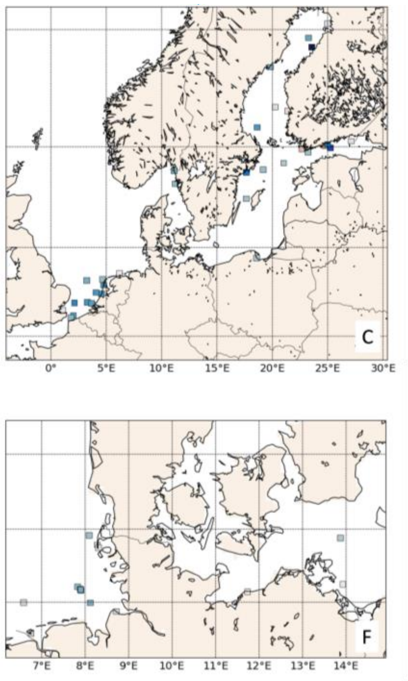
Biogeochemistry: Surface Chlorophyll





- DA drives dynamical changes in chlorophyll through changed physical conditions.
- SST assimilation improves coastal chlorophyll forecasts (Baltic Sea & southeastern North Sea).
- Northern North Sea sees increased chlorophyll errors.
- Small differences in chlorophyll between DA runs: 0.07 mgChl/m³ (coarse), 0.03 mgChl/m³ (fine).

Summary

Two DA experiments:

1. SST-DA – Assimilates only satellite SST data.
2. SST-TS-DA – Assimilates both satellite SST and station temperature-salinity data.

- Both experiments effectively reduce SST and SSS RMSE in the North and Baltic seas.
- Assimilating more datasets highlights the importance of improving forecast accuracy, such as incorporating station salinity data to constrain salinity gradients, particularly in the transition region.
- In some cases, such as the Gulf of Finland, station data assimilation introduces localized errors, suggesting the need for optimized localization radii.
- BGC variables, such as surface chlorophyll, experience dynamic changes.